6-21-2011

Analyzing Past and Predicting Future Droughts with Comprehensive Drought Indices for Arkansas-Red River Basin

Lu Liu
University of Oklahoma Norman Campus, liuemma2@ou.edu

Yang Hong
University of Oklahoma Norman Campus, yanghong@ou.edu

Analyzing Past and Predicting Future Droughts with Comprehensive Drought Indices for Arkansas-Red River Basin

Lu Liu[1], Yang Hong[1], James E. Hocker[2], Mark A. Shafer[2], Lynne M. Carter[3], Jonathan J. Gourley[4]

(1) Remote Sensing Hydrology Group, School of Civil Engineering and Environmental Science, University of Oklahoma, liuemma2@ou.edu, yanghong@ou.edu; (2) Oklahoma Climate Survey;
(3) Southern Climate Impacts Planning Program and Coastal Sustainability Studio; (4) National Severe Storms Laboratory

Introduction

This study intends to examine the past and predict future drought scenarios for Arkansas-Red River Basin with comprehensive drought indices in areas of study including meteorology, hydrometeorology, and hydrology. In this proceeding, we present some early results and analysis with the Standardized Precipitation Index (SPI) and the Palmer Drought Severity Index (PDSI). Historical climate data of 1900-2009 were archived to derive the drought indices calculation as well as projected A2 and A1B climate data from 16 statistically downscaled Global Climate Models (GCM). These datasets were applied in drought occurrence frequency and affected area prediction. The results from SPI and PDSI show that widespread drought took place in the 1910s, 1930s, 1950s and 1960s, which agrees with the historical climate record. Both SPI and PDSI indicate more frequent droughts in the second part of the 21st century, but predictions from the two indices were carried out under different scenarios.

The two indices describe future drought from a temporal and a spatial perspective. Future SPI indicates there might be 110 years of drought cycles occurring in the Arkansas-Red River Basin under A2, and future PDSI shows more severe droughts in the western portions of the Arkansas-Red River Basin under A1B.

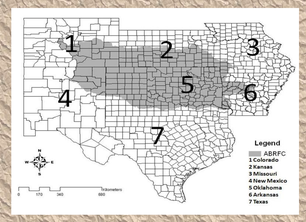

Figure 1. Arkansas-Red River Basin (ABRFC)

Data and Methodology

Table 1. Data used in research

Data Source	Data Parameters	Resolution	Time Period	Data Type
WCRP CMIP3	Precipitation Temperature	1/8 degree (~15 km)	1950-1999 (simulation) 2000-2099 (projection)	Gridded monthly data
PRISM	Precipitation	4 km	1900-2000 (simulation)	Gridded monthly data

Table 2. Drought indices information

Drought index	Inputs	Indicator for
SPI (Standardized Precipitation Index)	Precipitation	Meteorological drought
PDSI (Palmar Drought Severity Index)	Precipitation Temperature	Meteorological drought

Table 3. SPI classification

SPI Values	
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

Table 4. PDSI classification

Palmer Classifications	
4.0+	extremely wet
3.0 to 3.99	very wet
2.0 to 2.99	moderately wet
1.0 to 1.99	slightly wet
0.5 to 0.99	incipient wet spell
0.49 to -0.49	near normal
-0.5 to -0.99	incipient dry spell
-1.0 to -1.99	mild drought
-2.0 to -2.99	moderate drought
-3.0 to -3.99	severe drought
-4.0 and less	extreme drought

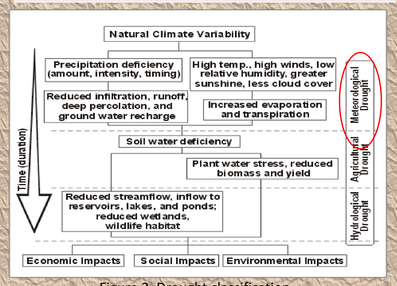

Figure 2. Drought classification

Results and Analyses

1. Past and Future Climate

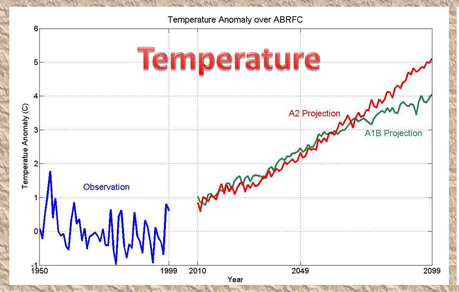

Figure 3. Temperature anomaly over ABRFC (Red line is the ensemble mean of 16 GCMs from A1B scenario)

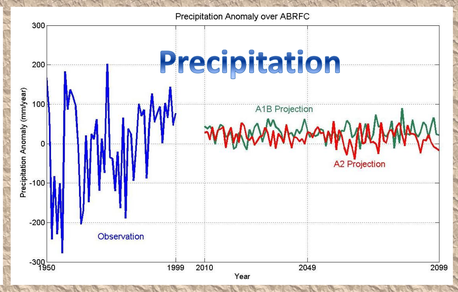

Figure 4. Precipitation anomaly over ABRFC (Red line is the ensemble mean of 16 GCMs from A1B scenario)

2. Past and Future Drought

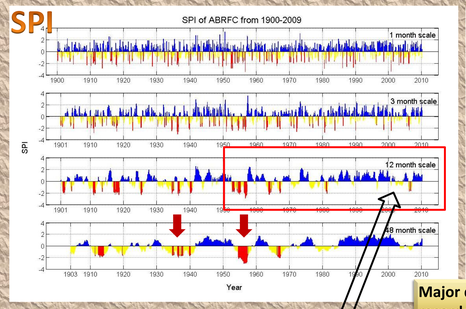

Figure 5. SPI over ABRFC from 1900-2009 (Red bars mean severe or extreme drought)

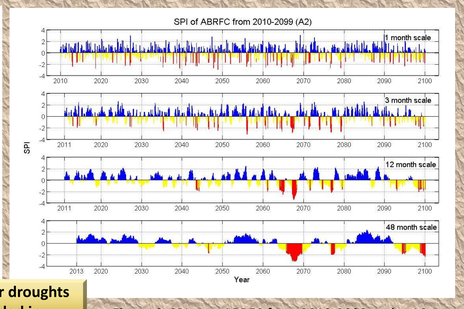

Figure 6. SPI over ABRFC from 2010-2099 under A2 scenario (Red bars mean severe or extreme drought)

Major droughts recorded in Oklahoma
- 1909-1918
- 1930-1940
- 1952-1958
- 2001-2002

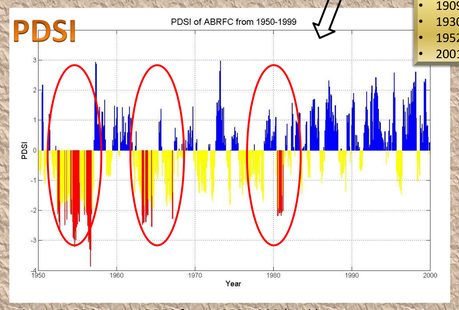

Figure 7. PDSI over ABRFC from 1950-1999 (Red bars mean severe or extreme drought)

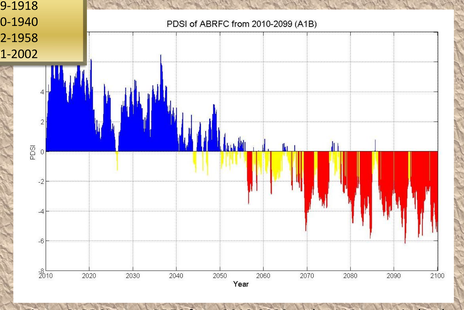

Figure 8. PDSI over ABRFC from 2010-2099 under A1B scenario (Red bars mean severe or extreme drought)

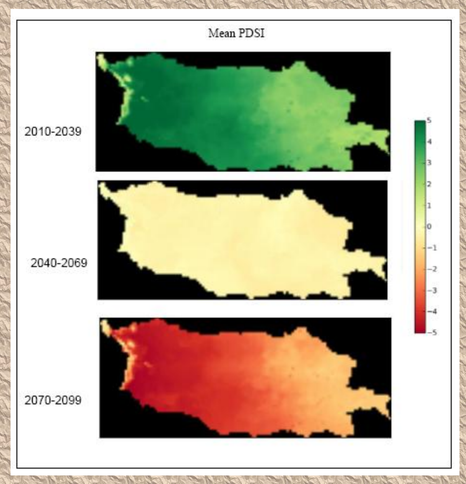

Figure 9. PDSI Project for the beginning, mid and late 21st century

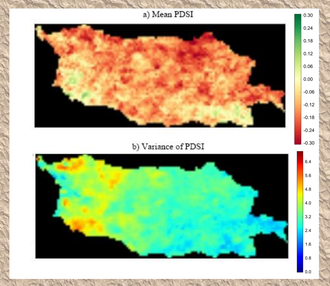

Figure 10. Mean and variance of PDSI over ABRFC from 1950-1999

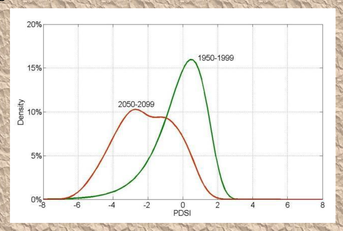

Figure 11. PDF of PDSI for ABRFC region under A1B scenario

3. Comparison

	Variables taken into account	Complexity	Cons
SPI	Precipitation	Easier	1. Doesn't consider evapotranspiration 2. Simple, not necessarily indicate drought 3. Requires quite a long period of precipitation record
PDSI	Precipitation and temperature	More difficult	1. Sensitive to soil type 2. All precipitation is treated as rain 3. Underestimation of runoff 4. Potential evapotranspiration is estimated from Thornthwaite model

Conclusions

- The temperature in the ABRFC displayed an upward trend after 2010 and it is projected to increase by 4-5 degrees by the end of the century. Precipitation however does not show a discernible trend overall, although the A2 scenario shows a slight decreasing trend after 2050.
- The two indicators both capture the major droughts in the 1950s and the 1960s. SPI and PDSI agree quite well from 1950 to 1999 but not for the future period.
- According to the SPI, ABRFC is under wet conditions for the first half of the 21st century, but precipitation becomes less abundant after 2060 which leads to a severe drought in the mid to late 2060s followed by another severe drought in the late 2070s. This indicates a possible drought cycle of 110 years looking back at the drought occurrence throughout 20th and 21st century.
- According to PDSI, it appears that overall this region is going to get drier and the western portions of the ABRFC region will experience a more severe drought than the eastern portions during the next 90 years. The simulation does however indicate that a wetter period will occur from 2010 - 2039.

Acknowledgement

This research is funded by the SCIPP program. We thank National Weather Center, OK for their computing resources and we also acknowledge the colleagues in the Remote Sensing Hydrology Group (RSHG) for technical support. In addition, we acknowledge the modeling groups, the Program for Climate Model Diagnosis and Inter-comparison (PCMDI) and the WCRP's Working Group on Coupled Modeling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.

Selected References:
[1] Dai, A., K. E. Trenberth, and T. Qian, 2004. A global data set of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming. J. Hydrometeorology, 5, 1117-1130.
[2] McKee, T.B.; N.J. Doesken; and J. Kleist. 1993. The relationship of drought frequency and duration to time scales. Preprints, 8th Conference on Applied Climatology, pp. 179–184. January 17–22, Anaheim, California.
[3] Palmer, W.C., 1965. Meteorological drought. Research Paper No. 45. U.S. Weather Bureau.
[4] Wells, N., S. Goddard, et al., 2004. A Self-Calibrating Palmer Drought Severity Index. Journal of Climate 17(12): 2335-2351.
[5] Wilby RL, Wigley TML 1997. Downscaling general circulation model output: A review of methods and limitations. Prog Phys Geogr, 21:530–548.
[6] Nakic´enovic´ , N., et al., 2000. IPCC Special Report on Emissions Scenarios. Cambridge University Press, Cambridge, UK.
[7] National Weather Service River Forecast Center: http://www.srh.noaa.gov/abrfc/
[8] National Integrated Drought Information System: http://www.drought.gov/portal/server.pt/community/drought_gov/202